Netted Full Spectrum Sensor

(NFSS)

SBIR Phase I Final Report

For
USACECOM RDEC I2WD

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13. ABSTRACT (Maximum 200 words)

The overall objective of this Phase I project was to provide a Netted Full Spectrum Sensor (NFSS) Operations Management Systems (OMS) for engineering decision-makers to perform tradeoffs in sensor requirements and design parameters, and to support staff officer decisions in real-time mission planning and and execution. The NFSS system will support a full suite of state-of-the-art ground based and air delivered multi-intelligence sensors to provide full coverage of the MASINT spectrum. PSI developed the architecture design for the NFSS-OMS, and identified needed modules to ensure tasking and missions of disparate MASINT operational sensors are coordinated by the NFSS. The architecture also provides a Common Operating Picture of the battlefield with the information derived from the sensor systems. The NFSS-OMS is also designed to support mission planning for both pre and post deployment to optimize sensor emplacement, tasking, and information gathered. In building the OMS architecture, PSI demonstrated how it's advanced CAD technology provides for rapid development and support of complex real-time control systems. Existing models were combined using the General Simulation System (GSS) and Run-Time Graphics (RTG) capabilities to produce a simulation that demonstrated how the NFSS-OMS would work, and that provides a firm foundation for further development in Phase II.

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1. Introduction

The Netted Full Spectrum Sensor (NFSS) architecture relies on a full suite of state-of-the-art ground based and air delivered multi-intelligence sensors. To ensure that operational sensor taskings and missions are coordinated, and not mutually interfering or redundant, will require a management system as part of the NFSS.

The NFSS Operations Management System (OMS) will allow engineering decision-makers to perform tradeoffs in sensor requirements and design parameters, as well as support staff officer decisions in real-time mission planning and execution. Users will be able to view unfolding scenarios in faster-than-real-time simulations of mission outcomes for predictive assessments of alternative sensor and platform selection as well as multi-sensor tasking using what-if scenarios. Staff officers should be able to assess weaknesses in mission plans, predict possible failures, and recommend changes to sensor taskings in real time.

Once operations are underway, one must be able to monitor actual operations in real time and compare them to the simulated scenario to determine the differences. To accomplish this requires that a user interact with a simulation running in real time, taking inputs from actual observation data. One can then assess the effects of competing tasking opportunities, e.g., whether to prosecute a high priority target in lieu of an originally planned target. This will allow a user to take advantage of new/unforeseen targets of opportunity, or possibly abort a mission that is going badly, freeing sensor assets for reuse elsewhere.

Under Phase I, Prediction Systems, Inc. (PSI) developed the architecture design for the NFSS-OMS. This architecture identifies the modules that define the capabilities of the NFSS-OMS and satisfy the requirement for coordinating disparate MASINT sensor activity as well as provide a Common Operating Picture of the battlefield with the information derived from the sensor systems. The NFSS-OMS is also designed to support mission planning for both pre and post deployment to optimize sensor emplacement, tasking, and information gathered.

In addition to the specific efforts to design the architecture and demonstrate the critical pieces in operation, PSI has shown how it's Computer-Aided Design (CAD) technology provides for rapid development and support of complex real time control systems. Using the General Simulation System (GSS), and Run-Time Graphics (RTG) system, existing models were combined with new models to produce a simulation that demonstrates how the NFSS-OMS would work.

2. Objectives

The specific Phase I Technical Objective was to produce an overall system design and concept of operations for achieving dynamic situation assessment and prediction. The following list are the facilities from the Phase I proposal that were investigated along with a brief status summary:

- Provide easy-to-use graphical user interfaces at workstations or on laptops - for both Windows 2000/NT and Unix/Linux. – The RTG system used to develop the NFSS graphics interface provides all the functionality required by NFSS. The environment is supported on both workstations and laptops as well as Windows and Unix platforms.

- Provide large screen display support. The Data Wall at AFRL, Rome, NY is an example of this type of facility, and one that PSI can interface to. – Initial technical discussions and demonstrations of the AFRL Data Wall were held at Rome, NY.

- Provide for 3-D visualization. Various facilities (e.g., ERDAS, Open-Map, JMAP, and facilities being developed by ARL) can be used by PSI to provide this capability. – Initial analysis of the facilities needed by NFSS do not require 3-D. However, PSI tools provide the ability to view the battlespace in 3-D.

- Request and receive real-time inputs from other tools or data sources for creation or modification of databases, use as scenario or equipment/model parameters, determine measures of effectiveness, sensor position or flight path optimization criteria, etc. – The sensor interfaces were tested using simulated systems. The NFSS prototype established connections with these simulated systems as if they were real.

- Maintain local databases to support the local planning functions. Monitor requests from other tools for data - for security and other purposes. – The NFSS-OMS prototype demonstrated the use of several databases that were maintained including raw sensor data and fused sensor data.

- Create many detailed mission scenarios quickly and interactively while simulations are running. This involves the use of hierarchies of entities and their corresponding iconic representation visually. It also requires the ability to quickly create complex paths of movement, e.g., flight paths, with multiple waypoints, velocities, altitudes, etc. – Dynamic deployment of new sensors, flight paths, and UAV payloads was demonstrated as part of the NFSS-OMS demonstration.

- Recognize prescribed measure thresholds and set off corresponding alarms, e.g., when a hostile element is within range of detection by friendly sensors. Alarms can be sent or received from other tools in the network. – This capability is part of the WARNING process and is described within the NFSS-OMS design.

- Determine optimal taskings and mission outcomes based upon optimization runs. – This capability is part of the OPTIMIZATION facility and is described within the NFSS-OMS design.

- Evaluate results of simulated missions, obtaining data collection and effectiveness measures (MOEs). Determine probabilities and accuracies of detection, correlation mechanisms, identification mechanisms, success rates, etc. – These issues are addressed throughout the NFSS-OMS design document. Particular focus on this issue is included in the description for the sensor fusion facility.

- Recognize requests and automatically send real-time outputs to other tools or data sinks, e.g., the ACE-ASAS, ACT-CGS, ACS-GPF and JSTARS. – The NFSS-OMS addresses this issue in two areas of the design. The first is the interface to other systems including sensor systems and other control and management systems. The other is the automatic response facility that is included as part of the NFSS-OMS design.

3. Research Conducted

The prime objective of the Phase I was to develop an architecture for the NFSS-OMS. This NFSS-OMS architecture addresses the capabilities to meet the design requirements. These capabilities are described within the following subsections.

3.1 Development environment

PSI has a set of tools that are being used to develop the NFSS-OMS that are uniquely qualified to providing the capabilities needed to satisfy the stated objectives. These tools are:

- **General Simulation System (GSS)** – GSS is a simulation environment used to quickly build models and analyze complex systems. The GSS Optimization capability provides advanced optimization techniques to solve highly nonlinear design problems. This has been used to optimize protocol layer parameters, scenario deployments, design criteria, and select courses of action in real time. GSS provides several ways to interface to external systems including basic TCP/IP sockets, XML, DIS, and HLA. The interfaces support real time IO. GSS simulations have been successfully used in hardware-in-the-loop experiments and real-time planning tools.

- **Virtual Software Environment (VSE)** – VSE is software development environment using a graphical front end to architect and implement software systems. VSE is virtually identical to GSS without the simulation clock and most GSS models can be interchanged with VSE modules. This allows code developed within the simulation environment to be ported directly to the software environment.

- **Run-Time Graphics (RTG)** – RTG is an interactive run-time graphics system available to GSS and VSE. RTG provides a visual interactive facility to deploy and interconnect hierarchical entities, change scenarios, and measure the performance of a system while it is running. Users can change or instrument any part of a model and present the action on a high- resolution workstation or laptop through manipulation of icons, lines and instruments. Users can pan and zoom over multiple background overlays, interacting with various menus and dynamic elements.

GSS/VSE/RTG are essentially platform independent. Products built with these tools run without change on Windows NT/2000/XP, Sun Solaris, SGI IRIX, Linux, and IBM AIX.

3.2 Mission planning

Mission planning became quite different during the Gulf war. Because of the concern for loss of human lives, ground combat was avoided until absolutely necessary. Focus was on establishing and maintaining air superiority to allow continuous

preparation of the battlefield by the coalition forces led by the U.S. Part of the everyday tasks of the CINC's staff were the analysis and prioritization of targets, analysis of threats, analysis of weather, selection of coalition assets to assign to targets, planning for logistics and refueling, and planning for redirection of assets as the situation and priorities changed.

Although final decisions on specific missions were made at CINC headquarters, significant inputs came from many other planning facilities, including the national headquarters of the different coalition forces. This type of planning requires sharing information among various planners in geographically distributed locations. Each of these planners will have tools to support their different functions. But each may need inputs from a subset of the others, and be required to send information to another subset to form a consistent battlespace representation, common operational picture and predicted battlespace situation.

The NFSS needs to support both pre-deployment mission planning for preparation of the battlefield as well as post-deployment mission planning. In both cases, the NFSS needs to provide real-time and on-demand MASINT full spectrum coverage and data presentation in an integrated manner at all levels of intelligence from forward troops to the remote command CINC headquarters. These facilities will likely include large wall map displays with graphical illustrations that indicate the current situation for participants to see at a glance. It will also include individual and remote client workstations so that participants can work specific sensor groups with the most suitable planing tools.

Pre-deployment mission planning will consist of optimizing the emplacement of MASINT sensor resources within the battlespace to provide the most efficient coverage to generate the intelligence required for successful mission execution.

Post-deployment mission planning must provide an indication of the capabilities of the sensors that are already deployed and where new sensors are needed to cover critical areas of the battlefield.

Visualization of the battefield is a key element in being able to provide mission planning. PSI experimented with the use of sensor coverage maps during Phase I. A coverage map can be used to determine which areas of the battlefield are covered by different sensors. The coverage maps can also be used to show results of more than one sensor (of different types) to indicate what area is covered. Figure 1 shows a coverage map generated using the prototype NFSS-OMS requiring only one sensor to cover an area and Figure 2 shows the same deployment requiring two sensors to cover the area.

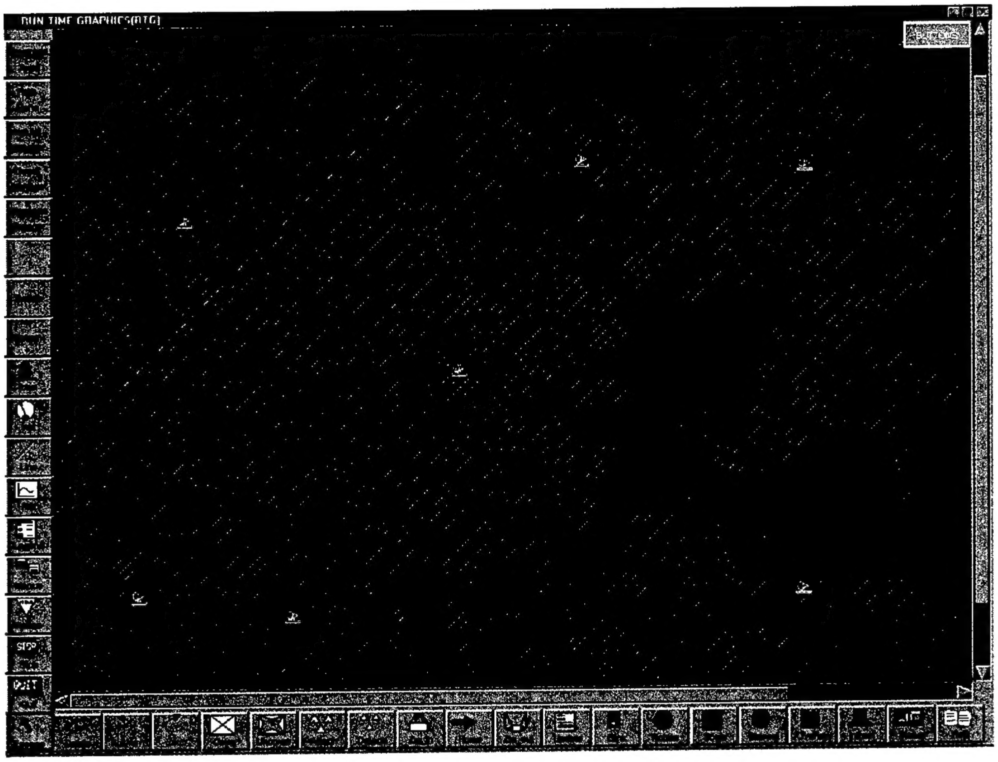

Figure 1. Sensor Coverage Map Requiring 1 Sensor

Figure 2. Sensor Coverage Map Requiring 2 Sensors

3.3 Sensor Management

To coordinate effective use of a fully integrated set of sensors as defined in the solicitation, the NFSS system requires interaction with other planned operational subsystems, e.g., INTEL, COMM, logistics, etc., as well as the control stations of new and existing sensor systems. Depending upon the mission plans being formed and questions being asked during a live operation, various information exchanges will be required with external systems as well as internal NFSS sites. To obtain the latest information, queries and responses will have to be interchanged with various staff positions, or directly to the automated systems used to support them. This interaction involves common databases shared by these systems, as well as their individual databases. Many of these systems will have to contribute their latest information to ensure the most accurate representation of the current state of operations, as well as provide the most accurate projections of the outcomes of proposed sensor tasks. This is a critical part of the NFSS system architecture, and it depends heavily upon different communications assets.

Clearly, coverage of the full spectrum of Measurement And Signature (MASINT) and EW / SIGINT emissions is a considerable undertaking. This implies the selection and tasking of multiple types of sensor assets, implying targeting, mission planning, communications planning, etc. With sensor types including RFINT, Chem-Bio, Seismic, Acoustic, Magnetic, Infrared, Imaging, and Weather, tasking multiple sets of sensors in real time is a significant operational management problem.

PSI has been developing planning and tasking tools to support CINC staff operations, determining information sources, designing system interfaces, and working with the developers of other systems to ensure seamless and timely passage of required information. This information is defined by the answers and measures of effectiveness that INTEL staff officers expect to obtain from the system. PSI has developed the embedded simulations that form the heart of these netted tools, and the real-time inputs for operational scenario and other data required to drive the simulations that predict sensor collection outcomes. These simulations are used by the staff officers to determine optimized sets of targets, taskings, and mission plans.

3.4 Sensor Fusion

The NFSS will receive reports from many MASINT sensors. The accuracy and level of detail from each of the sensor systems will vary with the system's capabilities. This will require the NFSS to include a database on the capabilities of each sensor type. The NFSS will need to receive and process this information and then provide this information in a coherent manner to the NFSS operator.

To avoid overwhelming the operator with raw data, the NFSS will need to provide different levels of sensor fusion. There are several levels of sensor fusion to aid this process:

- **Raw Data Filtering** – Some sensor systems will be providing a raw data stream of detection information. Some of these streams may consist of unprocessed OPFOR detections that may be continually repeated for each OPFOR being tracked. It is also possible that the sensor system may not be able to perform Specific Emitter Identification (SEI) thus being unable to correlate individual reports belonging to a single identity. Given the low-resolution of some of these sensors, it may appear that several entities exist where there may be only one. A raw data filter can be used to aggregate spot reports using a proximity filter. This filter would aggregate spot reports that are near each other thus reducing the amount of information that needs to be displayed by NFSS. This would not be performed for sensors that can perform SEI.

- **Disparate Sensor Fusion** – Since the NFSS will be receiving information from various sensors, it is assumed that different sensor systems will be reporting some of the same entities. The various sensor reports need to be aggregated into a single set of reports based on the information supplied by each sensor system. The combined entity must provide the information from each sensor to the NFSS operator. As an example, a seismic sensor may indicate the weight of a vehicle while an RF sensor may indicate the signal characteristics such as the frequency, bandwidth, and waveform type, that the vehicle's radio is producing. The sensor system capabilities database will be used to determine how the information should be aggregated. For instance, a higher-resolution sensor's position will be used in lieu of a lower-resolution sensor's position.

- **Entity Relationship Correlation** – Patterns within the sensor information received may indicate relationships between detected entities. Such patterns may be seen by correlating different RF transmissions or movement events following RF transmissions. These relationships can then be made available to the NFSS operator as graphical connections between the OPFOR icons on the display screen.

- **Organization Hierarchy Determination** – The pattern of entity relationships can be determined based on the evolving entity relationships along with other spot report information. Different RF frequencies used at a single site could be used to determine Command Post entities as well as how often they transmit. The relationships can then be used to develop the organizational structure of the OPFOR deployment. The NFSS will need to include a database of OPFOR capabilities to determine organizational elements from some of this information (e.g., radio types and the frequencies used by various command posts).

3.5 Display Management

Given that the simulation is built to support the mission scenarios to be analyzed, a graphical user interface must exist that allows the user to create and modify complex scenarios by manipulating icons, lines, instruments and other facilities built into the simulation. This includes deploying platforms and equipment, including targets, sensors, radios, satellites, jammers, etc. It also provides for creation of paths for movement of

satellites, aircraft, UAVs, helicopters, ground vehicles, and other platforms, and the selection of specific platforms to attach to those movement paths. This simulation can account for the dynamics of a fast moving scenario and measures of mission effectiveness as well as specific equipment performance. The nature of PSI's simulation facilities allows this to be done while the simulation is running. Furthermore, this allows real time comparison of alternative sensors, taskings, designs, etc.

Models exist for allowing the user to click down many way points for a complex movement path, attach one or more specified platforms to that path, and have them move individually or together to follow the path prescribed by the mission. The user can assign equipment and C2 decision elements to each platform so that as they move, they can send and receive electronic signals and messages, and react as they would using smart models guiding the platforms. This allows alternatives to be created, tested, and compared on-the-fly.

While interfacing with a running simulation, the user can interactively describe ranges for unknown parameters, e.g., waypoints along movement paths, to optimize specified measures of effectiveness. The optimization facilities built into GSS will then run as many simulations as desired to first determine if a feasible solution exists, and then to come up with an optimal set of parameters.

After the sensor information has been fused to provide a concise presentation to the NFSS-OMS operator, the ability to drill down through a composite entity to view the raw sensor data should be provided. This can easily be accomplished using the hierarchical graphics capabilities inherent within the GSS, VSE, and RTG and tools.

The technology embedded in these tools, for determining optimized parameters by running a large number of simulations automatically, has evolved to a point where users of the existing tools are now thinking well beyond their future concepts of one or two years ago. The technology for sharing models of hierarchies of entities, and the use of hierarchical icons to represent these entities has also evolved to allow extremely rapid development of simulations of huge complex scenarios. These simulations can be instrumented in many ways, and the resulting measures of performance and effectiveness can be used to produce the design envelopes for the sensors, sensor mixes, and approaches to multi-sensor tasking.

3.6 Information Sharing

The NFSS will not be the only system that needs to collect and track sensor information on the battlefield. The NFSS-OMS will need to include interfaces to support data sharing with other management and decision aid systems and databases. This interface must support automatic sharing of data in both directions. Information received from other management systems must be incorporated with the received sensor data and provided on the operator's screen.

Data can be extracted from local database management systems that typically reside on servers. Examples of database systems are ORACLE, SYBASE, ACCESS, etc.

Depending upon security levels, one may need to go through a procedure to scrub files that will be mixed with lower levels of classification. In these cases, files may be formatted during the extraction process. Canned request forms or panels can be stored to make it easy for users to do this.

Situational information may be distributed across multiple distributed local databases. Each tool could contain its own local database, as opposed to storing the data for all tools in a centralized database. (We do not preclude a centralized repository.) Updates to this local database can be coming in from other tools and databases via the real time inputs channels. The NFSS OMS control system will feed them through the database update and extraction module for input to the database. Elements of this database will be available to the simulation, optimization and control systems of the NFSS OMS. Subsets of this database will be stored in formats for high speed processing in support simulations. These subsets will be stored in the immediate databases required for specific scenario runs.

4. NFSS-OMS Architecture

The NFSS-OMS prototype was built using GSS. Figure 3 shows the architecture for the NFSS-OMS prototype that was developed during Phase I. This architecture consists of many of the main models that will be refined during Phase II. The following sections describe the top level models of the NFSS-OMS as they are currently implemented within the prototype developed during Phase I.

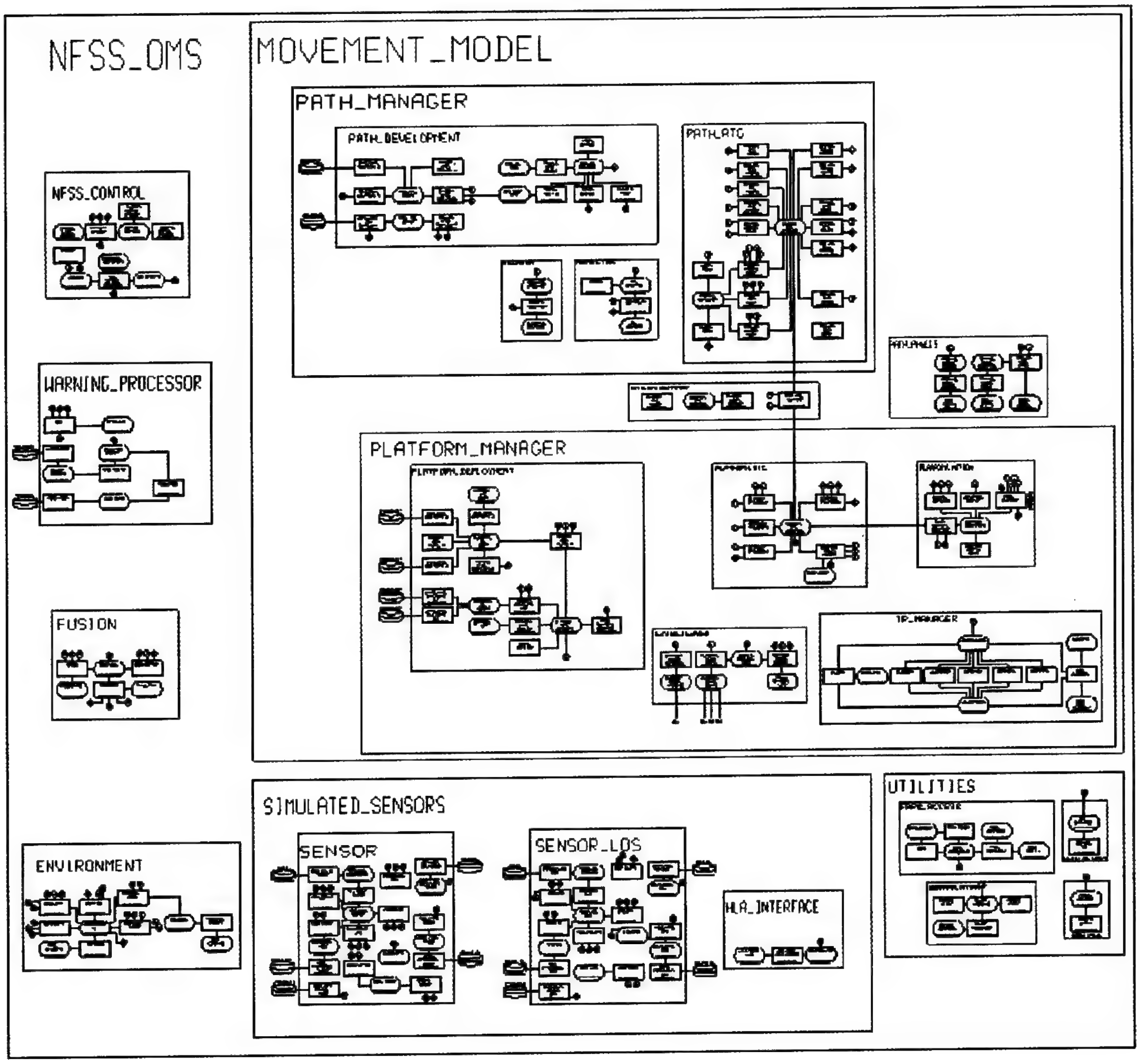

Figure 3. NFSS-OMS Model Architecture

4.1 NFSS_CONTROL Model

The NFSS_CONTROL Model is the main model within the NFSS-OMS that controls the actions and interfaces to the system. The activities controlled by this model are discussed in the following subsections.

4.1.1 Interactive Graphics Events

The graphics events generated by RTG from the user interactive interface are fielded within the NFSS_CONTROL Model. The following graphics events are currently supported:

- **Function Buttons** – RTG supports the use of 8 function buttons that can be assigned by the system developer on the button interface. These buttons change dynamically to support the activity that is currently being performed. The main set of buttons are currently used to invoke the Sensor Coverage Map and Path Manager capabilities. The Path Manager capability temporarily redefines the buttons to support defining and modifying paths for movement.

- **Icon Events** – The NFSS-OMS supports the deployment of different types of sensors to determine what parts of the area of interest have coverage. These sensors can be moved and their parameters updated.

4.1.2 Sensor System Interface Events

The NFSS-OMS supports connections from external sensor systems to receive sensor deployment and reporting information. During initialization, the NFSS-OMS starts a separate task to handle external sensor system connections made using TCP/IP. The NFSS-CONTROL model receives the sensor information from the connection server via a queue. The queue has been designed to periodically suspend graphic updates for short periods of time as needed to avoid overflow conditions when large amounts of data are streaming in.

4.2 WARNING_PROCESSOR Model

The WARNING_PROCESSOR Model attempts to associate an entity type based on the emitter characteristics detected. During initialization, the model reads 2 input files. The first file is an enumeration of the different types of waveforms that can be reported. The second file associates a given set of signal characteristics with a type of platform and an alert level.

For each spot report received, the WARNING_PROCESSOR model determines the associated platform type and warning level. If the warning level exceeds a specified threshold, the spot report is highlighted and a panel is displayed on the NFSS-OMS with the alert information. Figure 4 shows a sample alert panel from the prototype.

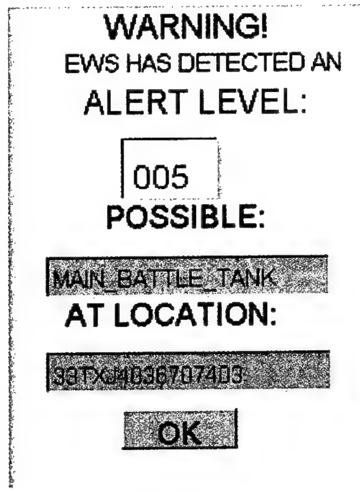

Figure 4. Sample Warning Processor Alert Panel

4.3 FUSION Model

The FUSION Model supports a simple 2 level fusion hierarchy based on spot report proximity. Spot reports with the same waveform information are fused if the locations reported are within a specified distance from each other.

By default, the NFSS-OMS displays fused spot reports. The user may, however, uncover the fused spot report to view the individual spot reports that were combined to form the fused report. Each spot report is color coded to indicate the waveform characteristics reported. A legend can be displayed showing the relationship between the spot report colors and the waveform types. Both fused and unfused reports can be clicked on to view an information panel with the spot reports information. A sample panel is shown in Figure 5.

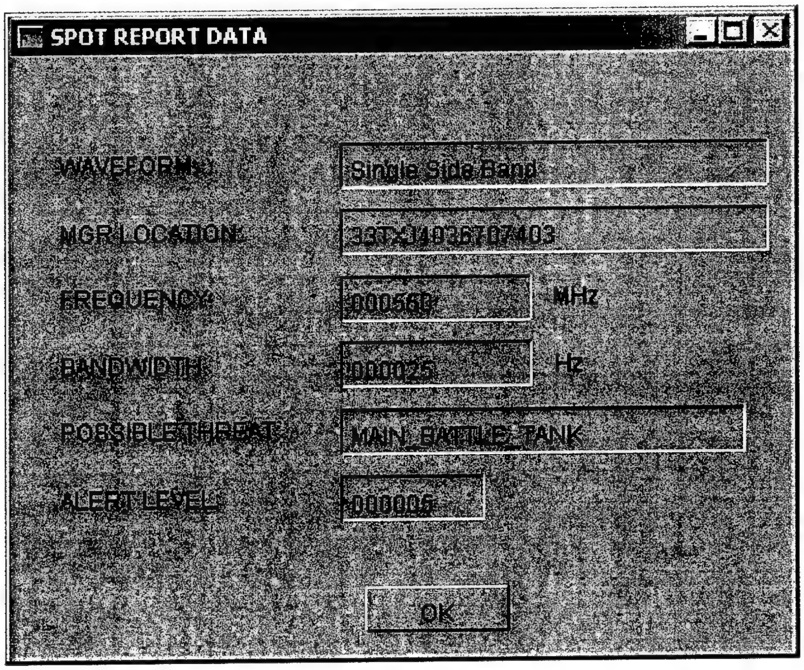

Figure 5. Sample Spot Report Information Panel

4.4 MOVEMENT Model

The movement manager allows for the creation, modification, and management of platform movement paths. The path manager allows great flexibility in creating, re-using, modifying, and managing flight paths. As shown in Figure 6, an aircraft flight path may be represented in three dimensions by up to 100 consecutive points.

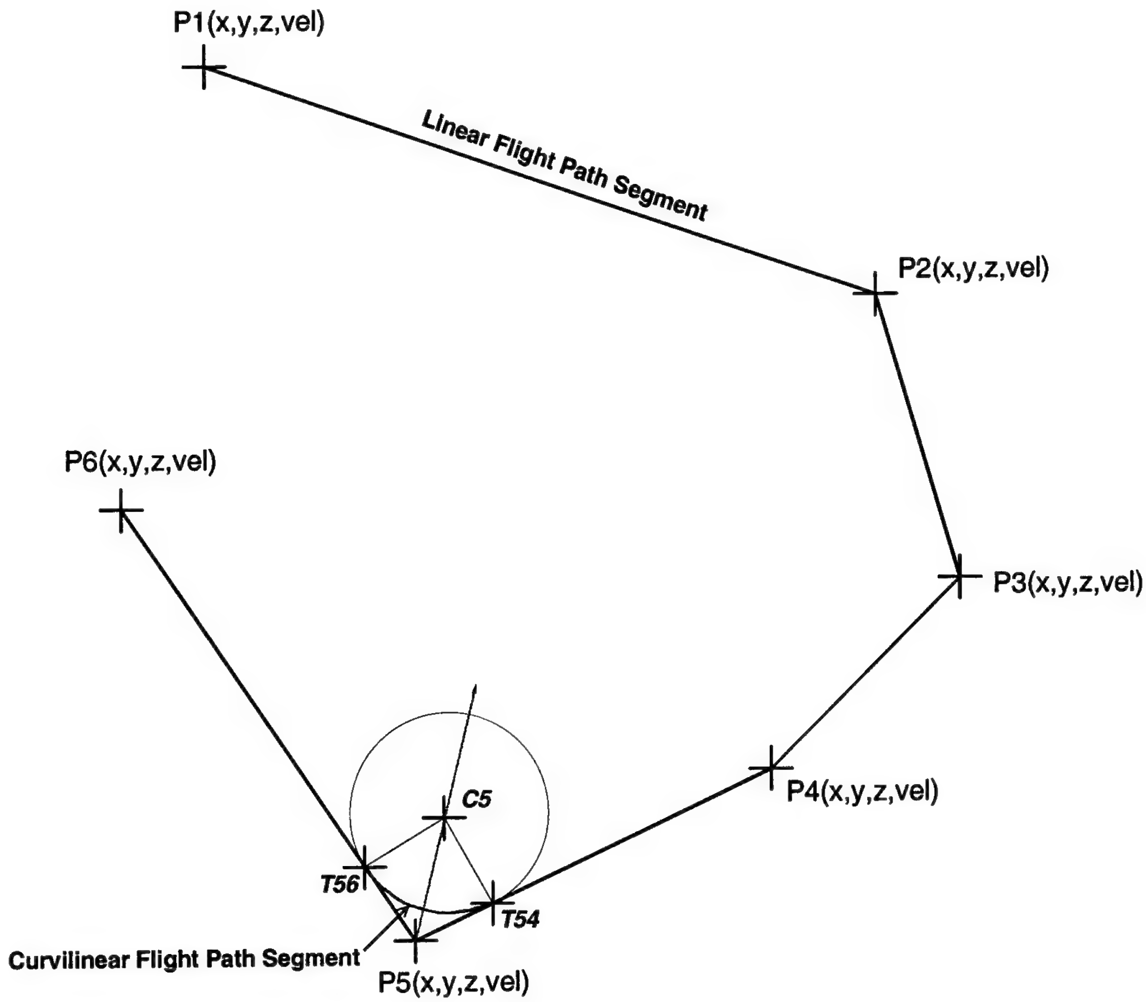

Figure 6. Flight Path Geometry

Points may be laid down, moved, and deleted interactively. The path profile model will compute the kinematics parameters required to move an aircraft through each segment at constant velocity. Any turning point on the path may be "smoothed" by an arc circle-segment as shown at the bottom of Figure 6. The arc is created using a *y*-G turn through the apex of the two connected flight path segments while ensuring a maximum allowed acceleration or G-force is not exceeded.

Paths may be designated as a loop (go back to initial point after last point) allowing racetrack patterns. Provisions exist to designate points between segments as delay points enabling aircraft to hover in stationary positions or to touch down and refuel. By constructing a vertical flight path segment, the aircraft emulates pop-up tactics. By further defining the topmost point as a delay point, the aircraft may perform surveillance or stand-off engagement functions.

Moving platforms are affiliated with path profiles to determine their motion dynamics. Any number of allowed platforms may be affiliated with any one path. Platforms may be inserted into active simulations and affiliated with paths interactively. When a platform is defined in a simulation it may be "loaded" with any of the available sensors.

4.5 SIMULATED_SENSORS Model

The NFSS-OMS supports the deployment of sensors to support mission planning. The sensors can be deployed, moved, and their parameters modified. The current prototype supports both SIGINT and LOS sensor types. The SIMULATED_SENSORS Model consists of 3 submodels described in the following sections. Information panels can be used to show the parameter settings of the sensors.

4.5.1 SENSOR Model

The SENSOR model simulates a SIGINT sensor. The model attempts to detect OPFOR entities as they emit signals. The ENVIRONMENT model is used to determine the signal loss between the emitters and sensors. Signal to Noise Ratios (SNR) that exceed the minimum detection threshold will cause a sensor to generate a spot report.

4.5.2 SENSOR_LOS Model

The SENSOR_LOS model is similar to the SENSOR model except that it detects OPFOR units that it has Line-Of-Sight with without the requirement of the OPFOR having to emit a signal. The ENVIRONMENT model is used to determine the whether a sensor has LOS with an OPFOR unit. Each unit that the SENSOR_LOS model detects will generate a spot report.

4.6 ENVIRONMENT Model

The ENVIRONMENT model uses Fast Propagation Prediction System (FPPS) to determine the propagation loss between emitters and SIGINT sensors. It is also used to determine whether LOS exists between OPFOR units and LOS sensors.

4.7 UTILITIES

The UTILITIES model contains the utilities that are used by the various models within the NFSS-OMS system. This model consists of the following 4 utilities:

- **FPPS_ACCESS** – The FPPS_ACCESS provide the interface to the FPPS library supporting foliage and propagation loss computations.
- **DDHHMMSS_ACESS** – The DDHHMMSS_ACCESS utility provides access to the library module that converts time between several formats.

- **POINT_TO_LINE_DISTANCE** – The POINT_TO_LINE_DISTANCE utility provides access to the library model that computes the distance from a point to a line.
- **ATANXY_ACCESS** – The ATANXY_ACCESS utility provides access to the library module that determines the positive or negative angle associated with a point relative to an origin.

5. Demonstrations

As part of the Phase I effort, PSI provided a demonstration of an NFSS-OMS prototype. The prototype demonstrated several of the required NFSS capabilities:

- **Graphical Interface** – The NFSS-OMS prototype makes use of all the capabilities of PSI's Run-Time Graphics (RTG) facility. This includes the ability to pan and zoom, display background overlays, deploy icons, etc. The demonstration showed how sensors could be deployed and configured from the NFSS-OMS. Figure 7 shows a configuration panel for one of the sensors. These parameters can be updated and expanded as the support for new sensor systems are identified and added. As a result of prototyping, additional requirements have been identified for implementation in Phase II. Examples are the graphical representation of spot report aging and special identifiers for new spot reports.

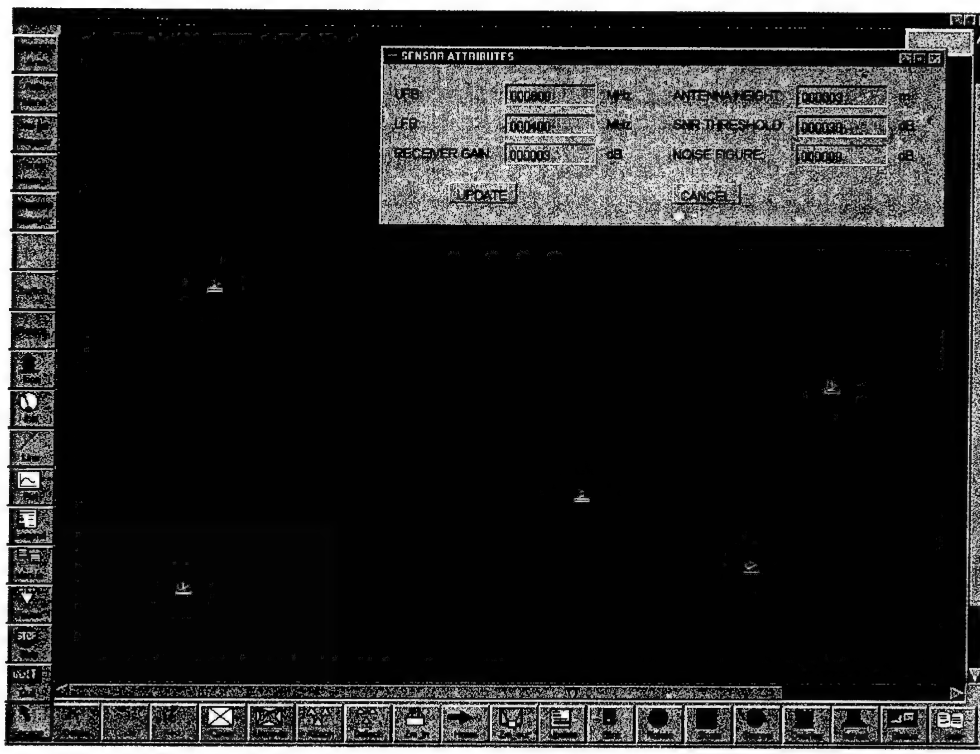

Figure 7. Updating Sensor Parameters

- **Sensor Fusion** – The sensor fusion currently implemented is the first order fusion process consisting of a simple proximity filter. This capability was demonstrated by showing how the spot reports on the NFSS-OMS screen were a reduced set of the deployment on the OPFOR screen. Phase II will provide additional levels of sensor fusion and operator selection of fusion parameters.

- **Sensor Interface** – When the NFSS is turned on, it automatically starts a separate process to listen for connections from sensor systems. The sensor systems were simulated in the demo by creating actual TCP/IP connections with the NFSS-OMS. Once a connection is establish, this process maintains the stream of data received from the sensor system and queues the information for processing by the NFSS-OMS. The sensor interface process uses the GSS capability for sharing data between processes.

- **Coverage Maps** – To support mission planning and effectiveness, the capability to show sensor coverage was demonstrated with the NFSS-OMS prototype. Coverage maps can be generated with any combination of sensor types. The number of sensors that are required to cover an area can also be specified. Figure 1 and Figure 2 show examples of coverage maps with different sensor requirement settings. Phase II will extend this capability to support additional parameter settings for each sensor type and analyze optimal alternatives for representing coverage visually.

- **Sensor Deployment** – In addition to receiving sensor deployment information from the sensor interface, the NFSS-OMS supports the interactive deployment of sensors directly on the scene. Sensor deployments and parameter settings are stored in a time ordered log file. These sensor locations and parameters can also be read in from a time ordered file of the same format as the log file. This provides the ability to replay scenarios and perform "what-if" type analyses.

- **Sensor Report Processing** – As sensor reports are received, they are processed by the fusion facility and displayed on the NFSS-OMS. Displayed OPFOR entities can be selected and an information panel brought up with the parametric information on the entity displayed. Phase II will support hierarchical spot report resolution where icons representing fused data can be uncovered to reveal the information that contributed to the fused data.

- **Airborne Platform Support** – The NFSS-OMS provides the ability to define airborne platform flight paths for deploying sensor packages. Once the waypoints of the flight path are defined, one or more airborne platforms can be assigned to that flight path. Each platform can then have one or more sensor packages assigned to it including C2 elements and communications equipment. Figure 8 shows a defined flight path with an airborne platform.

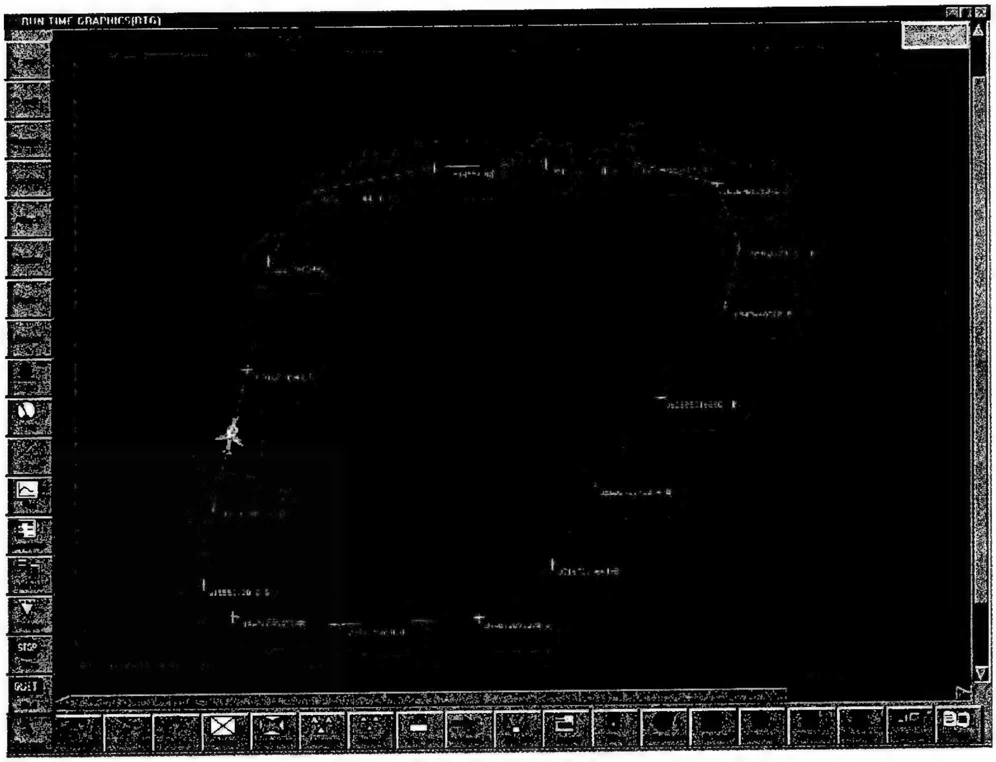

Figure 8. Flight Path Specification

To demonstrate the NFSS, additional simulations were developed to support testing the NFSS-OMS prototype. The simulation environment used for the demonstration is shown in Figure 9. The following simulations were included within the test suite:

- **OPFOR Simulation** – The OPFOR simulation includes a full graphical capability to deploy and update OPFOR entities. The simulation provides default OPFOR capabilities with the ability to easily change any entity parameters through graphical panels. The simulation records all transactions to a log file which can then be used to rerun the OPFOR deployment scenario. OPFOR parameters include the specification of RF emission characteristics.

- **Sensor Simulation** – A generic RF sensor system was developed to provide initial testing of the NFSS-OMS. The simulation includes a full graphical capability to deploy sensors and specify their capabilities parametrically via graphical panels. The simulation tracks all emissions from the OPFOR simulation to determine which sensors can detect the emitting OPFOR entity. Sensor detections are then reported to the NFSS-OMS.

The prototype demonstration test suite used the inter-processor communications capabilities of GSS:

- **TCP/IP** – The communications channel automatically established between the NFSS-OMS and the sensor systems used standard TCP/IP connections to represent a real world system connection. The NFSS-OMS establishes a server at initialization to accept and maintain connections with sensor systems. The Sensor simulation was designed to be a client.

- **High-Level Architecture (HLA)** – GSS has built in support for the HLA protocol. This protocol is a simulation interface standard designed to allow disparate simulations to communicate with each other. The GSS implementation of HLA provides the capability to interface multiple simulations without having to worry about the communications. For the prototype demonstration, the OPFOR entity information is published on the network for any other simulation to receive and process. The Sensor simulation, as well as the sensor models within the NFSS-OMS, subscribe to this information for processing.

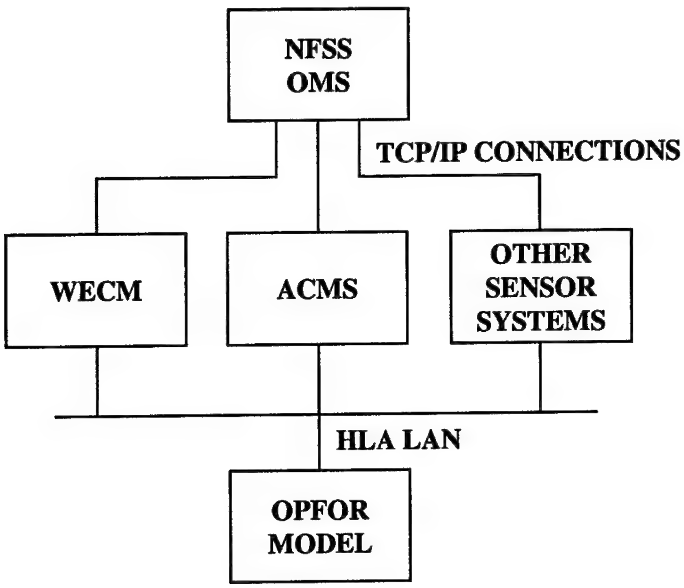

Figure 9. Phase I Demonstration Simulation Environment

The NFSS-OMS and the separate simulations can each run on separate computers over a network or on the same computer. For the Phase I demonstration, the NFSS-OMS was run on a computer by itself and the other simulations were run on a second computer. This separation was chosen to highlight the typical environment where the NFSS-OMS would be running by itself while receiving sensor information over the network.

5.1 Testing with UACEP Data

As part of meeting the WECM STO requirements, I2WD has been participating in the Future Combat System (FCS) virtual simulation experiments held at the Mounted Maneuver Battle Lab (MMBL) at Ft. Knox. The latest experiment was for the Unit of Action Concept Experimentation Program (UACEP). Although I2WD has laboratories where WECM prototypes can be analyzed from a technical perspective, the MMBL

experiments provide an environment where the value of WECM to the soldier can be analyzed more fully. These experiments help to meet the STO's objective of evaluating the visualization techniques used for WECM.

The UACEP experiment was held 1 – 25 April, 2002 at the MMBL. During this time I2WD supported the soldier training, Situational Training Exercise (STX), Pilot Test and the four Record Trials. The WECM Model Suite was used to model the WECM sensor system within the virtual simulation environment. The models use the nascent High Level Architecture (HLA) standard that is being mandated for newly developed models. To interface with legacy distributed virtual simulation environments such as the Distributed Interactive Simulation (DIS) environment, an HLA/DIS gateway was developed as part of the WECM Model Suite.

The WECM Model Suite contains a WECM Logger that is a simple federate that subscribes to all the HLA interactions within the federation and logs their contents to a file. Each data entry within the file is time stamped for further data analysis.

A new simulation was developed to process the WECM logs from the UACEP experiment and provide a stream of spot reports over a connection to the NFSS-OMS. The NFSS-OMS processed the inbound spot reports and provided the first level of data fusion. The fused data was then displayed graphically by the NFSS-OMS as shown in Figure 10.

5.2 Data Fusion

The NFSS will receive reports from many MASINT sensors. The accuracy and level of detail from each of the sensor systems will vary with the system's capabilities. This will require the NFSS to include a database on the capabilities of each sensor type. The NFSS will need to receive and process this information and then provide this information in a coherent manner to the NFSS operator.

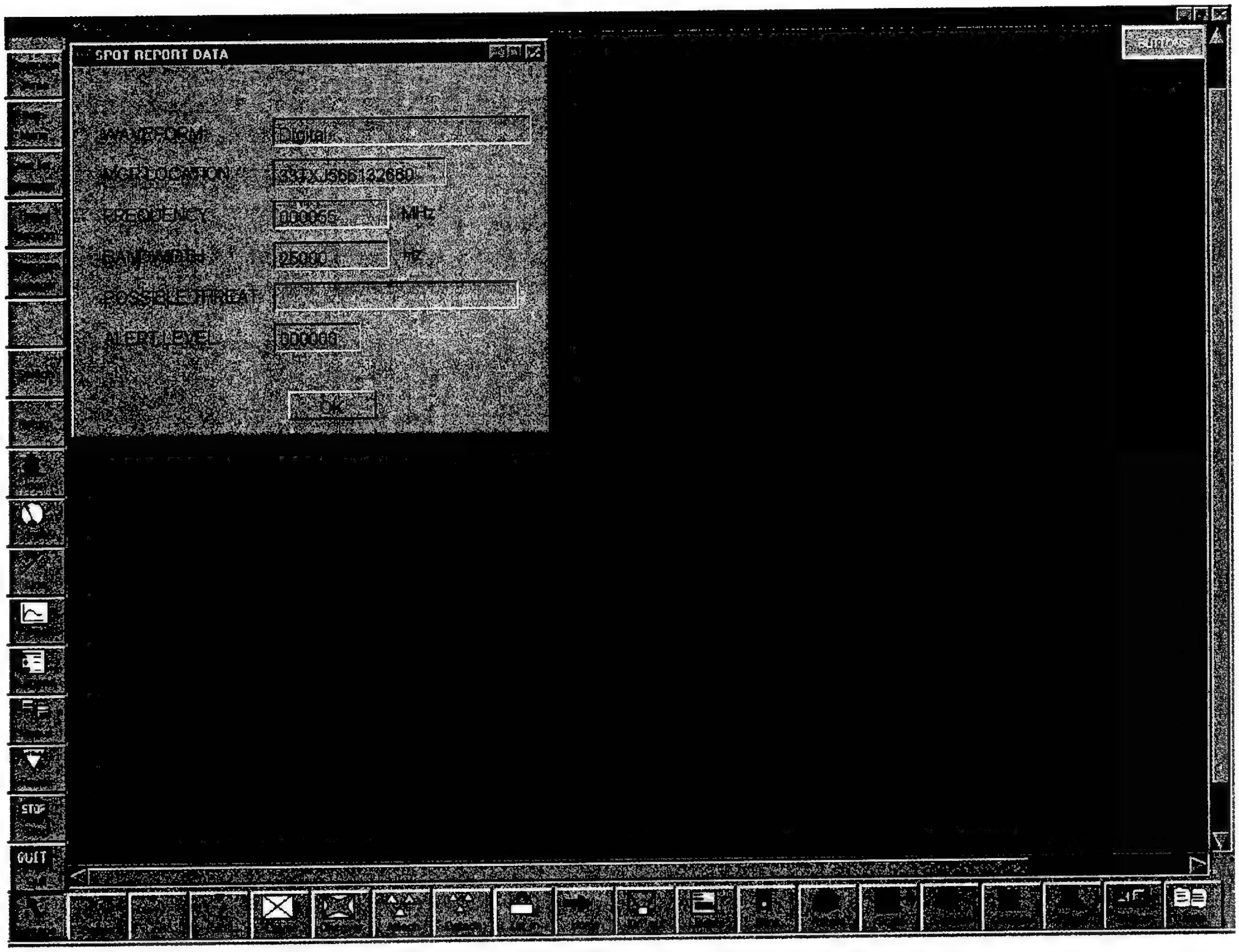

Figure 10. WECM UACEP Deployment with Sensor Fusion

To avoid overwhelming the operator with raw data, the NFSS needs to provide different levels of sensor fusion. The sensor fusion process should not result in lost data. The fusion process should result in a hierarchical database where higher levels in the hierarchy can be uncovered to view the information that was fused together. As an example, the icon for an OPFOR entity may be uncovered to provide several individual spot reports from various disparate sensors. Each of these spot reports may then be uncovered to view multiple spot reports from the same sensor system that were filtered.

The NFSS-OMS was updated to demonstrate this capability with the implementation of a 2-level sensor fusion hierarchy. This capability was tested with the WECM UACEP log files. The hierarchical fusion capability within NFSS-OMS currently fuses data on:

- Signal Frequency
- Signal Bandwidth

- Waveform Type
- Proximity

By default, the NFSS-OMS graphically displays fused spot reports on a background overlay. The color of the icon was used to represent the signal characteristics of the spot report to provide immediate feedback to the NFSS-OMS operator at a glance. Specific information can be viewed within a panel for individually selected spot reports. The capability to uncover a fused spot report was added to show the raw spot report information that was combined to generate the fused spot report. Each of these raw spot reports also supports the ability to bring up an information panel. Figure 11 shows the result of uncovering one of the fused spot reports in Figure 10.

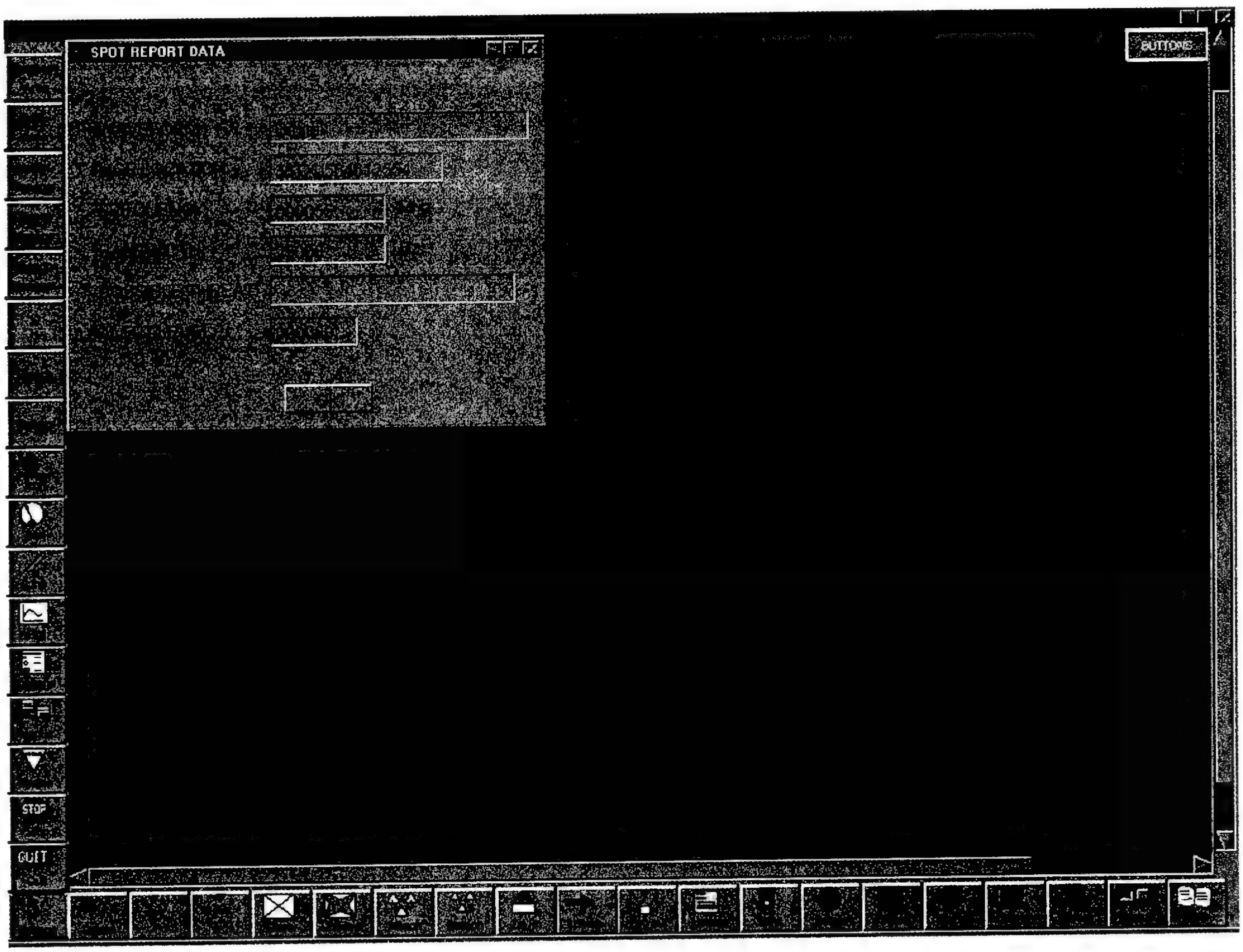

Figure 11. Uncovered Fused Spot Report Revealing Raw Spot Report Information

6. Technical Feasibility

PSI has been developing planning and tasking tools to support CINC staff operations, determining information sources, designing system interfaces, and working with the developers of other systems to ensure seamless and timely passage of required information for years. This information is defined by the answers and measures of effectiveness that INTEL staff officers expect to obtain from the system. PSI has developed the embedded simulations that form the heart of these netted tools, and the real-time inputs for operational scenario and other data required to drive the simulations that predict sensor collection outcomes. These simulations are used by staff officers to determine optimized sets of targets, taskings, and mission plans.

PSI has reviewed the NFSS requirements and feels that the use of its tools to develop the NFSS provides an extremely high probability of success. Several other systems being developed for the Army have identified the value of interfacing with NFSS and expresses support for a Phase II effort by PSI. The PSI development environment is uniquely suited to providing the capabilities needed to design, implement, and support the NFSS. In fact, the prototype developed during Phase I already demonstrates most of the features that will be required in the final system.

7. Phase II Plans

7.1 Technical Objectives

To satisfy the increasing need for intelligence information on the battlefield, new Measurement and Signal Intelligence (MASINT) sensors are being developed. Some of the requirements for these sensors are: remote deployability, remote control, low power, low probability of detection (LPD), low cost, and high reliability. These sensors typically utilize a communication network to pass control and collected data to a central control station. These stations would then be manned by someone in charge of maintaining that set of sensors.

The concept of a Netted Full Spectrum Sensor (NFSS) Operations Management System (OMS) was developed to manage these disparate sensor systems via an integrated interface. The NFSS-OMS will coordinate operational sensor taskings and missions to ensure sufficient intelligence gathering in an efficient manner to optimize use of limited resources and avoid excessive redundancy between disparate sensor systems. Mission planning needs to take into account the ability to deliver the required sensors where needed. To provide full coverage of the MASINT spectrum using an integrated approach, the NFSS-OMS system must support a full suite of state-of-the-art ground based and air delivered multi-intelligence sensors.

To coordinate the effective use of a fully integrated set of sensors, the NFSS-OMS system will require interaction with other planned operational subsystems, e.g., INTEL, COMM, logistics, etc., as well as the control stations of new and existing sensor systems. Depending upon the mission plans being formed and questions being asked during live operations, various information exchanges will be required with external systems as well as internal NFSS sites. To obtain the latest information, queries and responses will have to be interchanged with various staff positions, or directly to the automated systems used to support them. This interaction involves common databases shared by these systems, as well as their individual databases. Many of these systems will have to contribute their latest information to ensure the most accurate representation of the current state of operations, as well as provide the most accurate projections of the outcomes of proposed sensor tasks. This is a critical part of the NFSS-OMS system architecture, and it depends heavily upon different communications assets.

Clearly, coverage of the full spectrum of MASINT and EW / SIGINT emissions is a considerable undertaking. This implies the selection and tasking of multiple types of sensor assets, implying targeting, mission planning, communications planning, etc. With sensor types including RFINT, Chem-Bio, Seismic, Acoustic, Magnetic, Infrared, Imaging, and Weather, tasking multiple sets of sensors in real time is a significant operational management problem.

The Phase II Technical Objectives cover development of a set of operations sensor management tools that refine and extend the functional objectives derived in Phase I. The Phase II technical objectives are:

- **Develop a WECM Coordination Simulation** – This simulation will be used to design and optimize the WECM sensor coordination process and will be integrated within the NFSS set of tools. The development of this simulation will also include an analysis of the WECM coordination process with recommendations on how to implement the algorithms. These recommendations will become part of the WECM design transitioned to PM TRCS for implementation within the Joint Tactical Radio System (JTRS).

- **Develop a Sensor Interface Management Facility** – This facility will support the sensor system and management interfaces required by the NFSS. This facility will be used to provide the communications necessary to receive sensor status and reporting information as well as send sensor control information. It will also be used to support communications with other management facilities to share and coordinate acquired sensor data. This Sensor Interface Management Facility will be used to support the development of the ACMS sensor system currently under development.

- **Develop a Simulation Interface Facility** – This facility will provide the gateway capability to integrate the NFSS within multiple virtual simulation environments. It will be used to support the FCS experiments at the MMBL, Ft. Knox.

- **Develop an NFSS-OMS** – This tool will provide an implementation of the NFSS-OMS within a laptop environment. The NFSS-OMS will provide sensor control and optimization, both pre and post deployment, to support mission planning decissions. It will also integrate the aforementioned simulations and facilities as shown in Figure 12. Figure 12 also shows current projects that will directly benefit from the output of this Phase II.

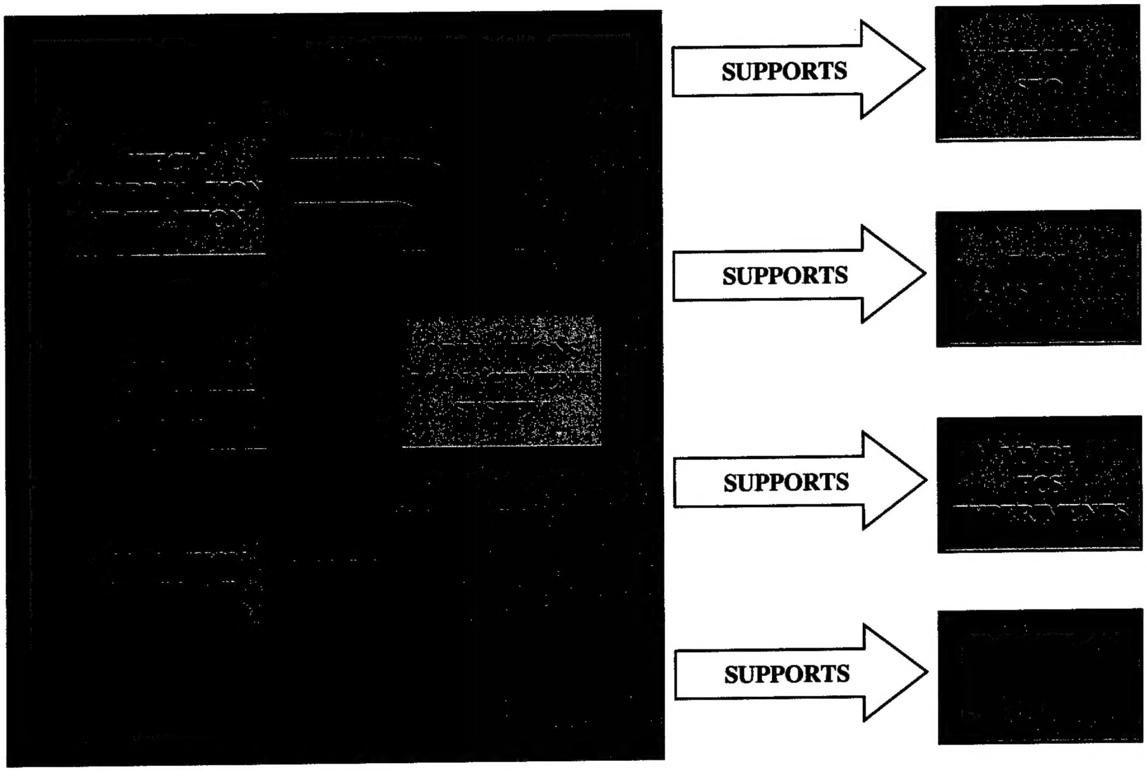

Figure 12. NFSS Components and Supported Projects

Because the requirements of this SBIR project are directly applicable to project work that PSI is currently doing with I2WD, our work plan is aimed at performing research and producing designs that can achieve demonstrable results in field tests/exercises in which these organizations participate.

The Intelligence and Information Warfare Simulation (IIWS) Laboratory supports research and development of enhancements to intelligence and information warfare system performance envelopes. The advanced software environment, current systems trainers, and simulators resident in the laboratory form a unique capability for the Army within I2WD. I2WD's mission is to provide the U.S. Army effective Intelligence and Information Warfare by providing an effective Signals Intelligence (SIGINT), Electronic Warfare, Measurement and Signature Intelligence (MASINT), Information Operations (IO) and Intelligence dissemination/fusion material capability to the U.S. Army through:

- Superior technology development, prototype demonstrations, and rapid transition of state-of-the-art techniques into systems.
- Development, production and fielding of specified equipment in support of Army and National Intelligence requirements and Law Enforcement Agencies (LEA).
- Engineering and management support to Program Executive Officers (PEOs) and their Program Managers (PMs) in the development, production and fielding of systems.

- Continuous improvement in productivity and fielding of systems.

Since the NFSS project requires integration of multiple sensor systems, we believe the IIWS environment to be an ideal proving ground for the NFSS OMS. The need to tie multiple tools and databases together is clearly required at the CINC and Ground Operations Center staff level. This operational environment places critical design constraints on an NFSS-OMS. These constraints imply synchronization with other tools and databases as well as synchronization of real and simulated time. It brings in the data coherency problem familiar to the parallel processing community. PSI has built into GSS the ability to transparently and effectively deal with distributed processing and also has the ability to interface with diverse databases. These solutions can be tested in the IIWS Laboratory.

7.2 Applicability

The NFSS-OMS being developed under this SBIR satisfies the requirement for coordinating disparate MASINT sensor activity and provides a Common Operating Picture of the battlefield with the information derived from the sensor systems. The NFSS-OMS is also designed to support mission planning for both pre and post deployment to optimize sensor emplacement and information gathered.

Several areas have already been identified that will benefit immediately from the development of the NFSS-OMS under Phase II:

- **Warfighter Electronic Collection and Mapping (WECM)** – The Science and Technology Objective (STO) initiated by the Intelligence and Information Warfare Directorate (I2WD) addresses the Army need to locate all enemy emitters on the battlefield and put them at risk. The approach is to utilize communications platforms as non-traditional Radio Frequency (RF) sensors to perform other functions such as threat detection, spectrum awareness, and mapping of emitters in the local area. Models of the WECM sensor have been built and used in the Future Combat System virtual simulation experiments for the last 2 years. Experiment feedback has indicated that WECM provides useful information to help the soldiers accomplish their mission. The WECM STO now requires a tool to analyze various options for sensor management. The WECM STO manager has indicated a desire to use the NFSS-OMS to satisfy this requirement. The endorsement letters signed by the WECM STO Manager along with the Mounted Maneuver Battlespace Lab (MMBL), PM-Prophet, and PM-RUS are attached at the end of this proposal.

- **Acoustic Canopy MASINT System (ACMS)** – The ACMS system is being developed under another SBIR Phase I under I2WD with Progeny Systems. This sensor system uses miniature acoustic transducers to locate and track personnel and vehicles in densely treed areas. The sensors can be deployed from UAVs. I2WD has requested that the ACMS be integrated with the NFSS for Phase II. PSI has already had discussions with Progeny Systems on

how the NFSS-OMS can be used to display sensor information and provide ACMS sensor coordination and control.

- **Electronic Support for the Objective Force** – This STO, planned to start in FY03, will address current sensor information distribution and communication requirements. The current plan is to expand the framework started under the WECM STO into a broader coverage of sensors. Initial discussions with I2WD indicate that the plan is to design the system to fit directly with the NFSS, and using the NFSS-OMS as the graphical front end for the system.

- **Future Combat System (FCS)** – The MMBL has a virtual simulation environment that is used to test the FCS Unit of Action of the Objective Force. The NFSS will provide the capability to manage the MASINT sensor assets used by the Unit of Action. This capability was specifically requested during the last FCS experiment. It will also provide feedback on the NFSS-OMS design and interface. The NFSS-OMS will also be used to provide feedback to the Ft. Huachuca analysts at the FCS experiment who require fused sensor data to assist in locating OPFOR Tactical Operation Centers (TOC). The MMBL has provided an endorsement letter along with the WECM STO Manger that is attached at the end of this proposal.